Section I:
ESPC Program Description and M&V Overview

This section contains two chapters. It introduces federal energy saving performance contracts (ESPC) and provides an overview of general measurement and verification (M&V) procedures. Chapter 1 discusses the purpose and scope of the document, program descriptions, and program resources. Chapter 2 describes general M&V concepts and issues associated with federal ESPCs.

- Chapter 1: Purpose and Program Description
- Chapter 2: Measurment and Verification: an Overview

1

Purpose and Program Description

1.1 ESPC Program Background

The Federal Energy Management Program (FEMP) was established within the U.S. Department of Energy to assist federal agencies in reducing facility costs. Many federal facilities can benefit from improved energy performance, reduced energy expenditures, and greater occupancy comfort. In addition, Executive Order 13123, signed by President Clinton on June 3, 1999, raises the energy use reduction goals for federal facilities. It establishes a goal to reduce energy consumption per square foot by 20 percent by the year 2000, 30 percent in 2005, and 35 percent in 2010, relative to a 1985 baseline.

By making capital investments in energy conservation measures (ECMs), federal facility managers can often reduce operating expenditures substantially. Frequently, however, capital funds are not available for such projects. A third party may see this lack of capital as an opportunity to purchase and install new equipment at a facility in exchange for a share of the federal agency's energy cost savings. If the third party guarantees a specific level of savings, the arrangement is known as an energy savings performance contract, or ESPC. For contracts with federal agencies, both energy service companies (ESCOs) and electric utilities may act as third parties.

An ESPC can apply to contracts involving renewable energy systems, water conservation, operations and maintenance (O&M) improvements, and other measures, as well as to contracts involving energy conservation measures and energy-efficient systems. Thus, here, “energy” is a generic term that includes fuel and electricity as well as water.

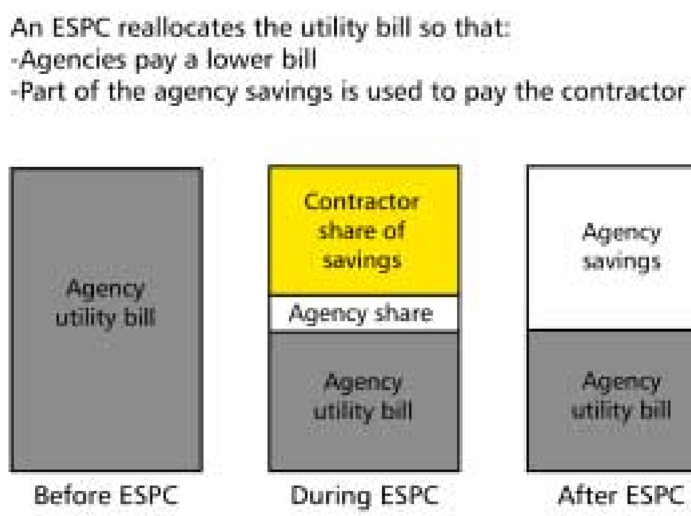
In an ESPC, a third party makes an investment in a facility that reduces its operating (primarily energy) costs. The third party then receives periodic payments from the agency that come from a share of the reduced cost savings. Figure 1.1 illustrates how the ESPCs work. After the contract period ends, the agency retains all of the savings.

A federal facility may enter into a performance contract to reduce overall energy use and/or to obtain new equipment. The contract can apply to both new construction and retrofits. The energy savings realized provide an income stream that will finance the project. In many cases, older, outdated equipment will be replaced with new equipment and control systems. As a direct result of the equipment change-out, the federal facility may also realize savings from:

- Decreased maintenance
- Increased productivity
- Improved comfort
- Improved environmental quality

While each portion of these benefits may be quantifiable, the focus of the Guidelines is to detail methods for quantifying energy, O&M, or water savings from the installation of ECMs, renewable energy systems, water efficiency products, or cogeneration projects.

Figure 1.1: Cash flow with ESPC



1.2 Purpose and Scope of the FEMP Guidelines

The purpose of this document is to provide guidelines and methods for measuring and verifying the energy and cost savings associated with federal agency performance contracts. It is intended for federal energy managers, federal procurement officers, and contractors implementing performance contracts at federal facilities. For ESPC projects, agencies should choose M&V methods that provide an appropriate level of accuracy for protection of the project investment energy savings performance.

The "performance" aspect of performance contracting is affected by how savings are determined. M&V documents savings. Therefore, M&V is one of the most important activities associated with implementing performance contracts. It is also the second most crucial contract negotiation issue, after pricing.

This M&V document has two primary uses:

- It serves as a reference document for specifying M&V methods and procedures in delivery orders, requests for proposals (RFPs), and performance contracts.
- It is a resource for those developing project-specific M&V plans for federal performance contracting projects.

By using this document, federal agencies will have confidence that their projects are verified (with respect to what was installed and the savings achieved). They will have followed procedures that can be applied with consistency to similar projects throughout all geographic regions and that are impartial, reliable, and repeatable.

This is Version 2.2 (2000) of the Guidelines; Version 2.0 was published in 1996. This version contains the following updates to the 1996 version:

- A discussion of ESPC responsibility issues and how they affect risk allocation.
- Quick M&V guidelines including procedural outlines, content checklists, and option summary tables.
- Measure-specific guidelines for assessing the most appropriate M&V option for common measures.
- New M&V strategies and methods for cogeneration, new construction, operations and maintenance, renewable energy systems, and water conservation projects.
- Editorial updates of the chapters for improved content consistency and readability.

1.3 How to Use the Guidelines

The M&V Guidelines are a general reference and guide to specifying measurement and verification methods for federal ESPCs. The Guidelines are divided into 8 sections consisting of 35 chapters, plus 4 appendices; at the front of each section is a brief summary of the section chapters' contents:

- Section I, Chapters 1 and 2, provides an introduction to ESPC concepts and an overview of M&V. Chapter 2, Tables 2.3–2.5 provide a summary and index of the measure-specific M&V methods included in this document.
- Section II, Chapters 3 through 5, gives procedures for incorporating M&V in an ESPC. Chapter 3 is an overview of the process. Chapter 4 describes details associated with M&V plan preparation. Chapter 5 presents “quick-start” Guidelines references including summary tables and checklists.
- Sections III, IV, V, and VI contain descriptions of measure-specific M&V methods for energy retrofits; these four sections discuss M&V methods that are based on M&V Options A, B, C, and D, respectively.
- Section VII, Chapters 26 through 31, contains descriptions of measure-specific M&V methods for water conservation measures.

- Section VIII, Chapters 32 through 35, presents M&V method descriptions for other types of measures including new construction, operation and maintenance, cogeneration, and renewable energy.

It is recommended that readers new to M&V read through Sections I, II, and Appendix A (definition of terms) in their entirety. Once the basics are understood, the reader can choose which parts of the remaining sections address the specific needs of the ESPC project in which he or she is involved. For example, if the project involves a lighting efficiency measure, the reader should study the M&V methods summarized in Table 5.2 (Lighting Efficiency Retrofits—M&V Methods and Responsibilities), evaluate the level of risk allowable for the measure, make a preliminary selection of the appropriate M&V method, and read the detailed description of the method (i.e., method LE-B-01, presented in Chapter 13).

For readers more familiar with M&V plan development, the summary documents presented in Chapter 5 provide a quick reference to the procedures and components associated with M&V plan preparation and review. Chapter 2 describes contract responsibility issues, which are summarized in Table 2.1 and described in section 2.2.1. Responsibility issues that impact cost-savings risk allocation is an important new topic that needs to be understood before developing an ESPC. Chapters 3 and 4 provide details that are worth reviewing concerning M&V plan development.

1.4 ESPC Program M&V Resources

Measuring and verifying savings from ESPC projects requires special project planning and engineering activities. M&V is an evolving science, although several common practices exist. These practices are documented in several resources described below and include the International Performance Measurement and Verification Protocol (IPMVP) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Guide 14P. These resources may be classified as general protocols (IPMVP), technical guidelines (ASHRAE 14P), or application-specific guidelines (FEMP Guidelines 2.2).

1.4.1 IPMVP

The 1998 IPMVP is a voluntary consensus document written by and for technical, procurement, and financial personnel in government, commerce, and industry. The IPMVP provides an overview of current M&V techniques and sets a framework for verifying third-party-financed energy projects for public (including federal) and private sector projects. The IPMVP is intended to be used as the basis for preparing program M&V guidelines, such as this document. The FEMP M&V Guidelines represent a specific application of the IPMVP to federal projects. The FEMP Guidelines outline procedures for specifying M&V in the preparation of requests for proposals, for evaluating proposals, and for establishing the basis of payment for energy savings during the contract. They are intended to be fully compatible and consistent with the IPMVP. For more information on the IPMVP, visit the web site at http://www.ipmvp.org.

1.4.2 ASHRAE Guideline 14

ASHRAE Guideline 14: Measurement of Energy & Demand Savings, First Public Review Draft, April 2000, is a proposed guideline for calculating energy savings associated with performance contracts. It introduces generic M&V approaches and describes detailed analysis procedures associated with completing M&V. In addition, it presents instrumentation and data management guidelines and describes methods for accounting for uncertainty associated with models and measurements. (For more information, please visit the Web site at http://www.ahsrae.org.)

1.4.3 FEMP Resources

The FEMP M&V Guidelines provide guidance on selecting the appropriate M&V effort for ESPC projects. It does not, however, contain detailed cost/benefit guidelines on selecting an M&V approach, establishing an appropriate level of accuracy, and creating a budget for the many different energy conservation measures (ECMs) and particular contract situations that can occur under ESPCs. For information not covered in the Guidelines, federal agency staff can contact their DOE Regional Office for assistance (for contacts and resources, please visit the Web site at http://www/eren.doe.gov/femp/financing/femp_services_who.html).

2

Measurement and Verification: An Overview

This chapter is an overview of the M&V concepts and issues associated with federal ESPCs. Also included are summaries of M&V Options A, B, C, and D. The last portion of this chapter discusses the degree of rigor required in the M&V effort.

2.1 General Approach to M&V

Facility energy (O&M or water) savings are determined by comparing the energy use before and after the installation of energy conservation measures. The "before" case is called the baseline; the "after" case is referred to as the post-installation or performance period. Proper determination of savings includes adjusting for changes that affect energy use but that are not caused by the conservation measures. Such adjustments may account for differences in weather and occupancy conditions between the baseline and performance periods.

In general,

$$\text{Savings} = (\text{Baseline Energy Use})_{\text{adjusted}} - (\text{Post-Installation Energy Use})$$

Baseline and post-installation energy use can be determined using the methods associated with several different M&V approaches. These approaches are termed M&V Options A, B, C, and D. A range of options is available to provide suitable techniques for a variety of applications. How one chooses and tailors a specific option is based on the level of M&V rigor required to obtain the desired accuracy level in the savings determination and is dependent on the complexity of the ECM, the potential for changes in performance, and the measure savings value.

The law (Title 42, United States Code, Section 8287) underlying the authority for federal facilities to enter into ESPCs requires guaranteed savings and, therefore, savings verification. The function of verification is to reduce agency risk. The challenge of M&V is to balance M&V costs and savings certainty with the value of the conservation measures.

2.2 M&V Requirements

The agency must exercise diligence to ensure that the M&V incorporated into the ESPC provides the appropriate level of performance verification for the specific conservation measures. To accomplish this, the M&V must include mandatory and option-specific requirements. The mandatory requirements common to all ESPC projects are:

1. Understanding ESPC issues that impact risk allocation to the agency or ESCO. *Review of responsibility issues impacting risk should be completed early in the development of the ESPC project delivery order.*
2. Preparation of a project measurement and verification plan. *This should be completed early in the development of the ESPC project delivery order.*
3. Documentation of the baseline conditions and verification of the potential for the conservation measures to generate savings.
4. Determination of savings in accordance with one of the four M&V options.

2.2.1 Contract Responsibility Issues

There are ESPC components that inherently specify how the risks associated with achieving estimated project cost savings are allocated between the agency and the ESCO. These components are generally related to the contract financial terms and the M&V methods agreed upon to determine savings. The contract issues affecting responsibility allocation are outlined in Table 2.1. The table lists the primary factors that impact the determination of savings and illustrates how their definition indicates which party—the ESCO or the government agency or perhaps neither—is responsible for each factor. Factors may include equipment performance (typically the ESCO's responsibility), changes in function of facility performance (typically the agency's responsibility), changes in weather (typically neither party's responsibility), and energy prices (typically the ESCO's risk if energy prices stay within a certain range, and the agency's risk if the prices fall outside that range).

Completing a responsibility table is a useful exercise for understanding the level of rigor required in the M&V plan, as it indicates which factors are the responsibility of the ESCO and thus need to be documented during the life of the contract. In general, but not always, a contract objective may be to release the ESCO from responsibility for factors beyond its control, such as building occupancy and weather, yet hold the ESCO responsible for controllable factors (risks), such as maintenance of equipment efficiency.

To reduce risks and the level of M&V rigor required, it is important to establish reasonable savings expectations before ECM or system installation. ESCOs may overestimate customer savings by relying on overly optimistic energy savings calculations. The federal agency should attempt to reach consensus with project sponsors on realistic energy savings estimates before issuing approval to proceed with installation. This approach establishes reasonable expectations up front that reduce the likelihood of a payment dispute following installation.

Table 2.1: ESPC Responsibility Issues

Category	Factor	Description
Financial	Interest rates	Neither the ESCO nor the agency has significant control over the prevailing interest rate. During all phases of the project, interest rates will change with market conditions. Higher interest rates will increase project cost, finance term, or both. The timing of the Delivery Order signing may affect the available interest rate and project cost. Clarify when the interest rate is locked in, and if it is a fixed or variable rate.
	Energy prices	Neither the ESCO nor the agency has significant control over actual energy prices. For calculating savings, the value of the saved energy may be constant, change at a fixed inflation rate, or float with market conditions. If the value changes with the market, falling energy prices place the ESCO at risk of failing to meet cost savings guarantees. If energy prices rise, there is a small risk to the agency that energy saving goals might not be met while the financial goals are. If the value of saved energy is fixed (either constant or escalated), the agency risks making payments in excess of actual energy cost savings.
	Construction costs	The ESCO is responsible for determining construction costs and defining a budget. In a fixed-price design/build contract, the agency assumes little responsibility for cost overruns; however, if construction estimates are significantly greater than originally assumed, the ESCO may find that the project or measure is no longer viable and drop it. In any design/build contract, the agency loses some design control. Clarify design standards and the design approval process (including changes) and how costs will be reviewed.
	M&V costs	The agency assumes the financial responsibility for M&V costs directly or through the ESCO. If the agency wishes to reduce M&V cost, it may do so by accepting less rigorous M&V activities with more uncertainty in the savings estimates. Clarify what performance is being guaranteed (equipment performance, operational factors, energy cost savings) and that the M&V plan is detailed enough to verify it satisfactorily.
	Delays	Both the ESCO and the agency can cause delays. Failure to implement a viable project in a timely manner costs the agency in the form of lost savings and adds cost to the project. Clarify the schedule and how delays will be handled (e.g., penalties or price adjustments).
	Major changes in facility	The agency (or Congress) controls major changes in facility use, including closure. Clarify responsibilities in the event of a premature facility closure, loss of funding, or other major change.

Category	Factor	Description
Operational	Operating hours	The agency generally has control over the operating hours. Increases and decreases in operating hours can show up as increases or decreases in "savings" depending on the M&V method (e.g., operating hours improved efficiency of equipment vs. whole building utility analysis). Clarify if operating hours are to be measured or stipulated and what the impact would be should they change. If the operating hours are stipulated, the baseline should be carefully documented and agreed to by both parties.
	Load	Equipment loads can change over time. The agency generally has control over hours of operation, conditioned floor area, and intensity of use (e.g., changes in occupancy or level of automation). Changes in load can show up as increases or decreases in "savings" depending on the M&V method. Clarify if equipment loads are to be measured or stipulated and what the impact would be should they change. If the equipment loads are stipulated, the baseline should be carefully documented and agreed to by both parties.
	Weather	A number of ECMs are affected by weather. Neither the ESCO nor the agency can control the weather. Changes in weather can increase or decrease "savings" depending on the M&V method (e.g., equipment run hours efficiency improvement vs. whole building utility analysis). If weather is "normalized," actual savings could be less than payments for a given year, but will "average out" over the long run. Weather corrections to the baseline or ongoing performance should be clearly specified and understood.
	Life of equipment	Equipment life is dependent on the original selection (contractor controlled) and operations and maintenance. Warranties usually cover failures in the first year. Extended warranties (often tied to service contracts) are available and assure that the agency won't continue paying for equipment that is no longer functional. Clarify who is responsible for repair and replacement of failed components throughout the term of the contract.
	User participation	Many ECMs require user participation to generate savings (e.g., control settings). The savings can be variable and the ESCO may be unwilling to invest in these measures. Clarify what degree of user participation is needed, and utilize monitoring and training to mitigate risk. If performance is stipulated, document and review assumptions carefully and consider M&V to confirm the capacity to save (e.g., confirm that the controls are functional).
Performance	Equipment performance	Generally, the ESCO has control over the selection of equipment and is responsible for its proper installation and performance. The ESCO also generally is responsible for demonstrating that the new improvements meet expected performance levels including standards of service and efficiency. Clarify who is responsible for initial and long-term performance, how will it be verified, and what will be done if performance does not meet expectations.

Category	Factor	Description
Performance (cont'd)	Maintenance	Responsibility for maintenance is negotiable; however, it is often tied to performance. Clarify how long-term maintenance will be assured, especially if the party responsible for long-term performance is not responsible for maintenance. [As a primary source of long-term performance risk, this section on maintenance may be expanded].
	Operation	Responsibility for operation is negotiable and it can impact performance. Clarify how proper operation will be assured. Clarify responsibility for operations and implications of equipment control.

2.2.2 Measurement and Verification Plan

The M&V plan is a document that defines project-specific measurement and verification methods for determining the savings resulting from performance contracting projects. The plan may include a single option that addresses all the measures installed at a single facility or it may include several M&V options to address multiple measures installed at the facility. The ESCO prepares the project-specific M&V plan and submits it to the federal agency for review and approval.

The following material defines the general requirements for submitting a project-specific M&V plan. Issues and requirements associated with measure-specific M&V methods are described in Chapters 6–31. An overview of M&V plan content requirements and review procedures are provided in Chapter 5.

The steps, which can be iterative, for defining a project-specific M&V plan include the following:

- Identify goals and objectives.
- Specify the characteristics of the facility and the ECM or system to be installed.
- Specify by measure the M&V option, methods, and techniques to be used.
- Specify data analysis procedures, algorithms, assumptions, data requirements, and data products.
- Specify the metering points, period of metering, and analysis and metering protocols.
- Specify accuracy and quality assurance procedures.
- Specify the annual M&V report format and how results will be documented.
- Define budget and resource requirements.

It is important to realistically anticipate the costs and level of effort associated with completing metering and data analysis activities. Time and budget requirements are often underestimated. Note that metering is just one part of a successful M&V program. Other key components include:

1. Properly defining the project and critical factors that affect energy consumption in order to prepare an appropriate M&V plan. These factors may include minimum energy standards established by an agency.
2. Completely defining baseline conditions such as comfort conditions, lighting intensities, and hours of operation.
3. Defining analysis equations and confidence required in the savings calculations in order to determine (1) the data that must be collected, (2) the period of time for data collection, and (3) the required accuracy of the data collection and analysis technique(s).
4. Calculating the value of the project in order to define a cost-effective level (accuracy) of M&V and addressing the relative value of the M&V information.
5. Using qualified staff and/or contractors to collect and analyze data.
6. Defining the data reporting and archiving requirements.

A project-specific M&V plan should demonstrate that any metering and analysis will be done in a consistent and logical manner and with a level of accuracy acceptable to all parties. The project-specific M&V plan must be submitted and approved by the federal agency before M&V activities begin. Final resolution of M&V and program design issues are left to the discretion of the federal agency.

2.2.3 Verification of the Potential to Generate Savings

The potential for the installed ECM to generate savings should be verified at regular intervals during the ESPC contract period. Verifying the potential to generate savings can also be stated as confirming that:

- The baseline conditions were accurately defined
- The proper equipment/systems were installed
- The equipment/systems are performing to specification
- The equipment/systems have the potential to generate the predicted savings.

Baseline Verification

Either the federal agency or the ESCO may define baseline conditions. Baseline physical conditions (such as equipment inventory and conditions, occupancy, nameplate data, energy consumption rate, control strategies, and so on) are typically determined through surveys, inspections, investment-grade audits, and spot or short-term metering activities. Baseline conditions are established for the purpose of calculating savings and in case operational changes that occur after measure installation mandate baseline energy use adjustments.

In almost all cases after the measure has been installed, one cannot go back and re-evaluate the baseline. It no longer exists! Therefore, it is very important to properly define and document the baseline conditions. Deciding what needs to be monitored, and for how long, depends on factors such as the stability of the baseline, the variability of equipment loads, and the number of variables that affect the load.

Post-Installation Verification

Post-installation M&V is conducted by both the ESCO and the federal agency to ensure that the proper equipment/systems that were installed are operating correctly and have the potential to generate the predicted savings. Verification methods may include surveys, inspections, and spot or short-term metering. Commissioning of installed equipment and systems is expected. Commissioning assures that the building systems perform interactively in accordance with the design documentation and intent. Commissioning is generally completed by the ESCO. In some cases, however, it is contracted out by the federal agency.

Regular Interval Post-Installation Verification

At least annually, the ESCO and the federal agency verify that the installed equipment/systems have been properly maintained, continue to operate correctly, and continue to have the potential to generate the predicted savings. Although annual reports are required for establishing savings guarantees, reports should be prepared at least quarterly. This ensures that the M&V monitoring and reporting systems are working properly, it allows fine-tuning of measures throughout the year based on operational feedback, and it avoids surprises at the end of the year.

2.2.4 Determining Savings

After the ECM or system is installed, energy savings are determined at one time, continuously, or at regular intervals as agreed upon by the ESCO and the federal agency in the project-specific M&V plan.

Baseline energy use, post-installation energy use, and energy (and cost) savings can be determined using one or more of the following M&V techniques:

- Engineering calculations
- Metering and monitoring
- Utility meter billing analysis
- Computer simulations (e.g., DOE-2 analysis).

The savings calculation approach is generally dependent on the M&V option and method selected for the measure. In some instances, a combined M&V option approach is best suited for the measure. For example, for a building with multiple measures, a combination of Option A and Option B may be used for different measures.

If long-term monitoring is not used in the M&V technique, the ESCO and the agency must accept that the agreed-to savings will not equal the savings that would be determined through a process that involves rigorous analyses and measurements. If important values are stipulated, both parties should understand that the savings determination will tend to be less accurate than if measurements were used to determine the values.

Numerous factors can affect energy savings during the term of a contract. These factors include weather, occupancy, operating hours, equipment schedules, equipment maintenance, and equipment loads. The ESCO must submit as part of the M&V plan a description of how they will adjust the baseline if post-installation conditions are different than baseline conditions.

2.3 Measurement and Verification Options

This document contains measurement and verification guidelines grouped into four categories: Options A, B, C, and D. The options are generic M&V approaches for energy and water projects. Options A, B, C, and D are consistent with those defined in the 1998 International Performance Measurement and Verification Protocols (IPMVP). Having four options provides a range of approaches to determine energy savings with varying levels of uncertainty, cost, and methodology. A particular option is chosen based on the project-specific features of each ESPC. These features include the following:

- The complexity of the ECMs.
- The objective of the agency with respect to minimizing the risk of savings being achieved.
- The potential for changes in key factors between the baseline period and the performance period.
- The measures' savings value.

The options differ in their approach to the level and duration of baseline and performance period measurements. M&V evaluations for both options A and B are made at the retrofit or system level. Option C evaluations are made at the whole-building or whole-facility level. Option D evaluations, which involve computer simulation modeling, are made at either the retrofit or the whole-building level (for model calibration purposes).

Option A involves using stipulated and measured values of key factors needed to determine energy savings. Options B and C involve using spot, short-term, and continuous measurements. Option D may include spot, short-term, or continuous measurements to calibrate the model.

Options A and B activities specifically determine retrofit-level performance and operation factors. Performance refers to equipment and system efficiency characteristics such as kW/ton for chillers or watts/fixture for lighting. Operation refers to equipment and system operating characteristics such as annual cooling ton-hours for chillers or operating hours for lighting. Option C performance factors are determined at the whole-building or facility level. Option C operational factors are determined by utility meter or sub-metered data. Option D performance and operational factors are modeled based on design specifications. Measurements can be used to verify input values and calibrate the model.

The four generic M&V options are summarized in Table 2.2 and described in more detail below. Each option has advantages and disadvantages based on site-specific factors and the needs and expectations of the agency. While each option defines a savings determination approach, all savings are estimates since savings cannot be directly measured.

Table 2.2: Overview of M&V Options

M&V Option	Performance and Operation Factors*	Savings Calculation	M&V Cost**
Option A—Stipulated and measured factors	Based on a combination of measured and stipulated factors. Measurements are spot or short-term taken at the component or system level. The stipulated factor is supported by historical or manufacturer's data.	Engineering calculations, component, or system models.	Estimated range is 1%-3%. Depends on number of points measured.
Option B—Measured factors	Based on spot or short-term measurements taken at the component or system level when variations in factors are not expected. Based on continuous measurements taken at the component or system level when variations are expected.	Engineering calculations, components, or system models.	Estimated range is 3%-15%. Depends on number of points and term of metering.
Option C—Utility billing data analysis	Based on long-term, whole-building utility meter, facility level, or sub-meter data.	Based on regression analysis of utility billing meter data.	Estimated range is 1%-10%. Depends on complexity of billing analysis.
Option D—Calibrated computer simulation	Computer simulation inputs may be based on several of the following: engineering estimates; spot, short-, or long-term measurements of system components; and long-term, whole-building utility meter data.	Based on computer simulation model calibrated with whole-building and end-use data.	Estimated range is 3%-10%. Depends on number and complexity of systems modeled.

*Performance factors indicate equipment or system performance characteristics such as kW/ton for a chiller or watts/fixture for lighting; operating factors indicate equipment or system operating characteristics such as annual cooling ton-hours for chillers or operating hours for lighting.
**M&V costs are expressed as a percentage of measure energy savings.

2.3.1 Option A

An Option A approach involves a retrofit or system level M&V assessment. The approach is intended for retrofits where either performance factors or operational factors can be spot or short-term measured during the baseline and post-installation periods. The factor not measured is stipulated based on assumptions, analysis of historical data, or manufacturer's data. Using a stipulated factor is appropriate only if supporting data demonstrates that its value is not subject to fluctuation over the term of the contract

Option A focuses on the physical assessment of equipment change-outs to ensure the installation is to specification. The potential to generate savings may be verified through observation, inspections, and/or spot or short-term metering conducted immediately before and/or after installation. Inspections or spot or short-term metering may also be conducted at regular intervals to verify an ECM's or system's continued potential to generate savings.

With Option A, savings are determined by measuring the capacity, efficiency, or operation of a system before and after a retrofit and by multiplying the difference by a stipulated factor. Stipulation is the easiest and least expensive method of determining savings. It can also be the least accurate and is typically the method with the greatest uncertainty of savings. This level of verification may suffice for certain types of projects in which a single factor represents a significant portion of the savings uncertainty. Option A is appropriate for projects in which both parties agree to a payment stream that is not subject to fluctuation due to changes in the operation or performance of the equipment (payments could be subject to change based on periodic measurements).

All end-use technologies can be verified using Option A; however, the accuracy of this option is generally inversely proportional to the complexity of the measure. In addition, within Option A, various methods and levels of accuracy in verifying performance/operation are available. The level of accuracy depends on the validity of assumptions, quality of the equipment inventory, and whether spot/short-term measurements are made. The penalty associated with low accuracy is not achieving the estimated measure savings and the associated utility bill cost reductions.

2.3.2 Option B

Option B involves a retrofit or system-level M&V assessment. The approach is intended for retrofits with performance factors and operational factors that can be measured at the component or system level. It is appropriate to use spot or short-term measurements to determine energy savings when variations in operations are not expected to change. When variations are expected, it is appropriate to measure factors continuously during the contract. Continuous measurements provide long-term performance data on the energy use of the equipment or system. These data can be used to improve or optimize the operation of the equipment on a real-time basis, thereby improving the benefit of the retrofit.

Option B verification procedures involve the same items as Option A but generally involve more end-use metering. Option B relies on the physical assessment of equipment change-outs to ensure the installation is to specification. The potential to generate savings is verified through observations, inspections, and spot, short-term, or continuous metering. The continuous metering of one or more variables may only occur after retrofit installation. Spot or short-term metering may be sufficient to characterize the baseline condition.

Option B relies on the direct measurement of end uses affected by the retrofit. Individual loads are monitored after ECM or system installation to determine performance. This measured performance is compared with a baseline model, also based on measurements, to determine savings.

All end-use technologies can be verified with Option B; however, the degree of difficulty and costs associated with verification increases as metering complexity increases. The task of measuring or determining energy savings using Option B can be more difficult and costly than that of Option A. The results, however, are typically more accurate. The use of periodic or continuous measurement accounts for operating variations. Spot or short-term measurements are sufficient for constant load retrofits. Using measurements more closely approximates actual energy savings than the use of stipulations as defined for Option A. Measurement of all end-use equipment or systems may not be required if statistically valid sampling is used. For example, the operating hours for a selected group of lighting fixtures or the power draw from a subset of representative constant-load motors may be metered.

2.3.3 Option C

Verification techniques for Option C determine savings by studying overall energy use in a facility and identifying the impact of conservation measures on total building or facility energy use patterns. The evaluation of whole-building or facility-level metered data is completed using techniques ranging from simple billing comparison to multivariate regression analysis. In general for federal ESPC projects, billing comparison methods are not recommended for estimating energy savings. Option C regression methods are valuable for measuring interactions between energy systems or determining the impact of projects that cannot be measured directly, such as insulation or other building envelope measures.

Option C involves procedures for verifying the potential to generate savings that are the same as Option A. Option C also involves determining energy savings during the contract term using whole-building metering data. Option C includes a physical assessment of equipment change-outs to ensure the installation is to specification. The potential to generate savings is verified through observation and inspection. The actual energy savings is determined from measured utility billing data and regression analysis modeling. All explanatory variables that affect energy consumption need to be monitored during the term of the contract for use in the model. Critical variables may include weather, occupancy schedules, set points, and operating schedules. Option C usually requires at least 9 to 12 months of continuous data before a retrofit and continuous data after the retrofit. The data can be hourly or monthly whole-building data.

All end-use technologies can be verified with Option C, provided that the reduction in consumption is larger than the associated modeling error. This option may be used in cases in which there is a high degree of interaction between installed energy conservation systems and/or the measurement of individual component savings is not cost-effective. Accounting for changes (other than those caused by the conservation measures) is the major challenge associated with Option C, particularly for long-term contracts.

2.3.4 Option D

Option D involves calibrated computer simulation models of component or whole-building energy consumption to determine measure energy savings. Linking simulation inputs to baseline and post-installation conditions completes the calibration. Characterizing baseline and post-installation conditions may involve metering performance and operating factors before and after the retrofit. Long-term whole-building energy use data may be used to calibrate the simulation(s).

Option D involves procedures for verifying the potential to generate savings that are the same as Option A. Option D also involves determining energy savings during the contract term through the use of a calibrated simulation analysis. Option D includes a physical assessment of equipment change-outs to ensure the installation is to specification. The potential to generate savings is verified through observation, inspection, and measurements. Manufacturer's data, spot measurements, or short-term measurements may be used to characterize baseline and post-installation conditions and operating schedules. The data serve to link the simulation inputs to actual operating conditions. The model calibration is accomplished by comparing simulation results with end-use or whole-building data. For whole-building models, option D usually requires at least 9 to 12 months of data before and after the retrofit. If continuous, post-installation data are used, the simulation model can be calibrated at regular intervals to update the savings estimates.

All end-use technologies can be verified with Option D, provided that the size of the drop in consumption is larger than the associated modeling error. This option may be used in cases where there is a high degree of interaction among installed energy conservation systems and/or the measurement of individual component savings is difficult. Accurate modeling and calibration are the major challenges associated with Option D. The building simulation model may involve elaborate models (such as DOE-2), spreadsheets, or vendor estimating programs. More elaborate models may improve accuracy and increase modeling costs.

2.4 M&V Methods

An M&V method is a measure-specific M&V approach based on one of the four M&V options. The M&V Guidelines present methods for determining energy savings for common ECMs. All of the methods for determining energy savings are based on the same concept: savings are derived by comparing usage after the retrofit to what the usage would have been without the retrofit (i.e., the baseline). The federal agency and the ESCO will select an M&V option and method for each project and then prepare a site-specific M&V plan that incorporates project-specific details, as discussed in this document.

Thus far, the Guidelines have focused on the generic M&V categories of Options A, B, C, and D, as defined in the IPMVP. This section summarizes the M&V methods, categorized by option and ECM technology, provided in this document. The ECMs covered are those that are most commonly implemented though performance contracts.

Table 2.3 is a summary of methods defined for different energy efficiency retrofits. Table 2.4 shows methods defined for water conservation measures. Table 2.5 summarizes methods for other types of measures. In the tables, the first column lists the method label that indicates the measure and the option the M&V method is based on. The second column indicates where the method description can be found in the Guidelines.

Table 2.3: Summary of M&V Methods for Specific Energy Retrofits

Method	Section/ Chapter	ECM	Option	Approach
LE-A-01	III/7	Lighting efficiency	A	No metering
LE-A-02	III/7	Lighting efficiency	A	Spot metering of fixture wattage
LE-B-01	IV/13	Lighting efficiency	B	Continuous metering of operating hours
LE-B-02	IV/14	Lighting efficiency	B	Continuous metering of lighting circuits
LC-A-01	III/8	Lighting controls	A	No metering
LC-A-02	III/8	Lighting controls	A	Spot metering of fixture wattages
LC-B-01	IV/15	Lighting controls	B	Continuous metering of operating hours
LC-B-02	IV/16	Lighting controls	B	Continuous metering of lighting circuits
CLM-A-01	III/9	Constant load motors	A	Spot metering of motor kW
CLM-B-01	IV/17	Constant load motors	B	Continuous metering of motor kW
VSD-A-01	III/10	Variable speed drive retrofit	A	Spot metering of motor kW
VSD-B-01	IV/18	Variable speed drive retrofit	B	Continuous metering of motor kW, speed frequency, or controlling variables

Method	Section/ Chapter	ECM	Option	Approach
CH-A-01	III/11	Chiller retrofit	A	No metering
CH-A-02	III/11	Chiller retrofit	A	Verification of chiller kW/ton
CH-B-01	IV/19	Chiller retrofit	B	Continuous metering of new chiller and cooling load
CH-B-02	IV/19	Chiller retrofit	B	Continuous metering of new chiller and cooling equipment
GVL-B-01	IV/20	Generic variable load project	B	Continuous metering of end-use energy use
GVL-C-01	V/22	Generic variable load project	C	Utility bill regression analysis
GVL-C-02	V/23	Generic variable load project	C	Utility bill comparison
GVL-D-01	VI/25	Generic variable load project	D	Calibrated simulation model

Table 2.4: Summary of M&V Methods for Water Conservation Measures

Method	Section/ Chapter	ECM	Option	Approach
WCM-A-01	VII/27	Water conservation measure	A	Stipulated operating factors, spot-measured performance factors
WCM-A-02	VII/28	Water conservation measure	A	Spot-measured operating and performance factors
WCM-B-01	VII/29	Water conservation measure	B	Short-term or continuously measured operating and performance factors
WCM-C-01	VII/30	Water conservation measure	C	Historical and current utility meter or sub-meter data
WCM-D-01	VII/31	Water conservation measure	D	Calibrated simulation model

Table 2.5: Summary of M&V Methods for Other Project Categories

Method	Section/ Chapter	ECM	Option	Approach
NC-A-01	VIII/32	New construction	A	Stipulated operating factors, measured performance factors
NC-B-01	VIII/32	New construction	B	Measured operating and performance factors
NC-C-01	VIII/32	New construction	C	Baseline simulation, post-installation billing data
NC-C-02	VIII/32	New construction	C	Baseline stipulation, post-installation billing data
NC-D-01	VIII/32	New construction	D	Calibrated simulation model
OM-01	VIII/33	Operation and maintenance measures	A, B, C, D	Various
COG-01	VIII/34	Cogeneration projects	A, B, C, D	Various
REN-01	VIII/35	Renewable energy projects	A, B, C, D	Various

2.5 Selection of M&V Methods and Rigor

Since the primary purpose of M&V is to validate payments or performance guarantees, the cost of M&V should be less than the payment amount or guarantee that is at risk. Consequently, the objective of M&V should not necessarily be to derive a precise energy savings number, but rather to ensure that ESCOs properly complete their projects and that the resulting energy savings are reasonably close to the savings claimed. The appropriate level of M&V rigor and accuracy is a level that protects the project investment and fulfills the intent of the federal legislative requirements.

In summary, the selection of an M&V method is based on:

- Project costs
- Expected savings
- Uncertainty or risk of savings being achieved
- Risk allocation between the parties (i.e., which party is responsible for the performance of the installed equipment and which party is responsible for achieving long-term energy savings).

A simple method of estimating payment risk can be based on the estimated project value, technical uncertainty, and project sponsor experience. Such a method assumes that, as a starting point, all projects will be inspected to verify the projects' potential to perform and estimate savings uncertainty and payment risk. A simple illustration of this method is shown below:

Sample Project	Estimated Savings	Estimated Uncertainty	Savings Risk
Small lighting	$50,000	10%	$5,000
Large custom	$500,000	20%	$100,000

An "M&V budget cap" is then established as a percentage of the project's payment risk before an M&V plan is specified. As illustrated, smaller projects consisting of predictable technologies have less payment risk (and thus a lower M&V budget cap) than large projects that include less predictable technologies. In the above illustration, for the "large custom" measure, two M&V approaches may be evaluated based on their "benefit/cost" ratio as indicated below. In this next example, M&V Method GVL-C-01 would appear to be the better approach.

Sample Project	Est. savings	Est. uncertainty (no M&V)	Savings risk (no M&V)	Proposed method	Est. M&V cost	Resulting savings uncertainty	Cost benefit ratio: M&V cost/risk reduction
Large custom	$500K	20%	$100K	GVL-C-01	$25K	10%/$50K	2.0
Large custom	$500K	20%	$100K	GVL-D-01	$50K	8%/$40K	1.2

Accuracy requirements for measuring and verifying savings are either defined by the federal agency in its RFP or negotiated with the ESCO. In either case, the required level of measurement and verification effort is specified in the contract between the federal agency and the ESCO in the form of the M&V plan. *This plan must be developed in early phases of a project's development to ensure that M&V is not left as an "afterthought" or that inadequate funding has been allocated to the required M&V activities.*

2.5.1 Factors Affecting Level of Effort and Costs

In general, the more rigorous the M&V, the more expensive it will be to determine energy savings. The factors that typically affect M&V accuracy and costs (some are interrelated) are listed below.

- Level of detail and effort associated with verifying baseline and post-installation surveys
- Sample sizes (number of data points) used for metering representative equipment
- Confidence and precision levels specified for energy savings analyses

- Duration and accuracy of metering activities
- Number and complexity of dependent and independent variables that are metered or accounted for in analyses
- Availability of existing data collecting systems (e.g., energy management systems)
- Contract term.

2.5.2 Selecting the Appropriate M&V Option and Method

As noted, the level of certainty and effort required to verify both a project's potential to perform and its actual performance will vary from project to project. The draft RFP, the actual contract, and/or the project-specific M&V plan should be prepared with serious consideration of what M&V requirements, reviews, and costs will be specified.

These are some factors that affect the decision of which M&V option, method, and technique to use for each ESPC project:

Value of ECM in Terms of Projected Savings
The scale of a project, energy rates, term of the contract, comprehensiveness of ECMs, the benefit-sharing arrangement, and the magnitude of savings can all affect the value of the ESPC project. The M&V effort should be scaled to the value of the project so that the value of the information provided by the M&V activity is appropriate to the value of the project itself. “Rule of thumb” estimates put M&V costs at 1% to 10% of typical project cost savings.

Complexity of ECM or System
More complex projects may require more complex (and thus more expensive) M&V methods to determine energy savings. In general, the complexity of isolating the savings is the critical factor. For example, a complicated HVAC measure may not be difficult to assess if there is a utility meter dedicated to the HVAC system.

When defining the appropriate M&V requirements for a given project, it is helpful to consider projects as being in one of the following categories (listed in order of increasing M&V complexity):

- Constant load, constant operating hours
- Constant load, variable operating hours
  - Variable hours with a fixed pattern
  - Variable hours without a fixed pattern (e.g., weather-dependent)
- Variable load, variable operating hours
  - Variable hours or load with a fixed pattern
  - Variable hours or load without a fixed pattern (e.g., weather-dependent).

Number of Interrelated ECMs at a Single Facility

If multiple ECMs are being installed at a single site, the savings from each measure may be, to some degree, related to the savings resulting from other measure(s) or other non-ECM activities at the facility. Examples include interactive effects between lighting and HVAC measures or between HVAC control measures and a chiller replacement. In these situations, it is probably not possible to isolate and measure one system in order to determine savings. Thus, for multiple, interrelated measures, Option C is almost always required.

Uncertainty of Savings

The importance of the M&V activities is often tied to the uncertainty associated with the estimated energy or cost savings. An ECM with which the facility staff is familiar may, subjectively, require less M&V rigor than ECMs that are less well known. In addition, if the ECM is similar to other projects that have been completed, and for which savings have been documented, the M&V results may be applied from the other project. If the ESCO specifies the baseline, it may be more appropriate to use M&V Options B or C to verify savings.

Responsibility (or Risk) Allocation between the ESCO and the Federal Agency

If an ESCO's payments are not tied to actual savings, M&V activities are not required. Likewise, if an ESCO is not held responsible for certain aspects of a project's performance, these aspects do not need to be measured or verified. The responsibility matrix and contract should specify how payments will be determined and thus what needs to be verified. For example, variations in the operating hours of a facility during the term of a contract may be a risk the federal agency takes. Also, operating hours may be determined by short-term and not continuous measurements for purposes of payment, in which case Option A may be appropriate.

Other Uses for M&V Data and Systems

Often, the array of instrumentation installed and the measurements collected for M&V can be used for other purposes, including commissioning and system optimization. Data and systems are more cost-effective if they are used to meet several objectives, and not just those of the M&V plan. In addition, savings could be quantified beyond the requirements of the performance contract. This information could be useful for allocating costs among different tenants, planning future projects, or allocating research.

2.5.3 Criteria for Selecting an M&V Approach

The four M&V options can be applied to almost any type of ECM; however, the rules-of-thumb listed below generally indicate the most appropriate M&V approach for an application.

Option A can be applied when identifying the potential to generate savings is the most critical M&V issue, including situations in which:

- The magnitude of savings is low for the entire project or a portion of the project to which Option A can be applied.

- The risk of achieving savings is low or ESCO payments are not directly tied to actual savings.

Option B, retrofit isolation, is typically used when any or all of these conditions apply:

- For simple equipment replacement projects with energy savings that are less than 20% of total facility energy use as recorded by the relevant utility meter or sub-meter.
- Energy savings values per individual measure are desired.
- Interactive effects are to be ignored or are stipulated using estimating methods that do not involve long-term measurements.
- The independent variables that affect energy use are neither complex nor excessively difficult or expensive to monitor.
- Sub-meters already exist that record the energy use of subsystems under consideration (e.g., a 277 Volt lighting circuit or a separate sub-meter for HVAC systems).

Option C, billing analysis, is typically used when any or all of these conditions apply:

- The equipment replacement and controls projects are complex.
- Predicted savings are relatively large (greater than 10% to 20%) as compared to the energy use recorded by the relevant utility meter or sub-meter.
- Energy savings values per individual measure are not desired.
- Interactive effects are to be included.
- Independent variables that affect energy use are not complex and excessively difficult or expensive to monitor.

Option D, calibrated simulation, is used in situations similar to Option C, or in addition when any or all of these conditions apply:

- New construction projects are involved.
- Energy savings values per measure are desired.
- Option C tools cannot cost effectively evaluate particular measures or their interactions with the building when complex baseline adjustments are anticipated.

2.5.4 Measure-Specific M&V Methods and Responsibilities

The M&V methods summarized in this section are organized by ECM and M&V option. For each measure, a table highlights the components of several M&V methods. The measures included are lighting efficiency (LE), lighting controls (LC), efficient constant load motors (CLM), variable-speed drive (VSD) installations, and chiller (CH) replacements. Tables 2.6–2.10 summarize the measure-specific M&V approaches, which are methods based on Options A or B. The ESCO and agency responsibilities and risks associated with each method are outlined in the tables.

As described previously, variable load/variable operating hour projects require more rigorous M&V than constant load/constant operating hour projects. The lighting efficiency and constant load motor measures are representative of constant load, constant operating hour projects. The lighting control measures are representative of constant load, variable operating projects. The variable-speed drive and chiller replacements are representative of variable load, variable operating hour projects.

For more details about developing M&V plans for these M&V methods, refer to Section III, Chapters 6–11 for Option A-based approaches; to Section IV, Chapters 12 - 20 for Option B-based approaches; to Section V, Chapters 21–23 for Option C-based approaches; and to Section VI, Chapters 24–25 for Option D-based approaches.

Measure Category: Lighting efficiency retrofit
Operating Factors: Operating hours
Performance Factors: kW/fixture or kW/circuit

Table 2.6: Lighting Efficiency Retrofits—M&V Methods and Responsibilities

	Method			
	LE-A-01	**LE-A-02**	**LE-B-01**	**LE-B-02**
Option	**A**	**A**	**B**	**B**
Approach	Minimal or no metering	Metering of fixture wattage	Metering of operating hours	Metering of lighting circuits
Fixture Counts	Survey which is checked to defined accuracy	See LE-A-01	See LE-A-01	See LE-A-01
Fixture Wattages	Fixture wattage table or manufacturer data	One time (pre- and post-) measurements of representative fixture wattages	Fixture wattage table or fixture measurements	Measured circuit wattage
Pre-installation Operating Hours	a) Stipulated based on documented estimates or b) stipulated based on short-term pre-installation monitoring	See LE-A-01	Assumed equal to post-installation hours, which are monitored	See LE-B-01
Post-installation Operating Hours	Same as pre-installation operating hours	See LE-A-01	Monitoring of operating hours	Measurement of circuit average power draw implies operating hours
Interactive Factors	a) Not allowed, or b) stipulated percentage or c) based on simulation	See LE-A-01	See LE-A-01	See LE-A-01
ESCO Responsibility	None	Performance	Operating hours or hours and performance	Performance and operating hours
Agency Responsibility	Performance and operating hours	Operating hours	Performance or none	None

Measure Category: Lighting controls retrofits
Operating Factors: Operating hours
Performance Factors: kW/fixture or kW/circuit

Table 2.7: Lighting Controls Retrofits—M&V Methods and Responsibilities

	Method			
	LC-A-01	**LC-A-02**	**LC-B-01**	**LC-B-02**
Option	**A**	**A**	**B**	**B**
Approach	Minimal or no metering	Metering of fixture wattages	Metering of operating hours	Metering of lighting circuits
Fixture Counts	Survey which is checked to defined accuracy	See LC-A-01	See LC-A-01	See LC-A-01
Fixture Wattages	Fixture or wattage table or manufacturer data	One time measurements of representative fixture wattages	Fixture wattage table or one time fixture measurements	Measured circuit wattage
Pre-installation Operating Hours	a) Stipulated based on estimates or b) stipulated based on short-term pre-install monitoring	See LC-A-01	Operating hours are monitored for representative samples of fixtures	The circuit measurement of average power draw also provides operating hours
Post-installation Operating Hours	a) Stipulated based on estimates or b) stipulated based on short-term post-install monitoring	See LC-A-01	Operating hours are monitored for representative samples of fixtures	The circuit measurement of average power draw also provides operating hours
Interactive Factors	a) Not allowed, or b) stipulated percentage, or c) based on simulation	See LC-A-01	See LC-A-01	See LC-A-01
ESCO Responsibility	None	Performance	Operating hours or hours and performance	Performance and operating hours
Agency Responsibility	Performance and operating hours	Operating hours	Performance or none	None

Measure Category: Constant Load Motor Retrofits
Operating Factors: Operating hours
Performance Factors: kW or RPM

Table 2.8: Constant Load Motor Retrofits—M&V Methods and Responsibilities

	Method	
	CLM-A-01	**CLM-B-01**
Option	**A**	**B**
Approach	Spot metering of motor kW	Spot metering of motor kW and monitoring of operating hours
Motor Counts	Survey checked to defined accuracy	See CLM-A-01
Baseline and Post-installation Motor Power Draw	Spot and/or short-term wattage/rpm measurements	Spot and short-term wattage/ rpm measurements
Pre-installation Operating Hours	a) Stipulated based on estimates, or b) stipulated based on short-term pre-installation monitoring	Assumed equal to post-installation hours which are monitored
Post-installation Operating Hours	Same as pre-installation operating hours	Monitoring of operating hours or kWh
Confirmation of Constant Load	a) Stipulated, or b) short-term metering of sample of motors	See CLM-A-01
ESCO Responsibility	Performance	Performance and operating hours
Agency Responsibility	Operating hours	None

Measure Category: Variable Load Motor Retrofits
Operating Factors: Operating hours, percent time at different loads
Performance Factors: kW or RPM

Table 2.9: Variable Load Motor Retrofits—M&V Methods and Responsibilities

	Method	
	VSD-A-01	**VSD-B-01**
Option	**A**	**B**
Approach	Spot metering of motor kW and RPM	Continuous metering of motor kW or controlling variables
Inventory of Motors and Drives/ Controls	Survey checked to defined accuracy	See VSD-A-01
Verification of System Operation	Functional verification of VSD operation	See VSD-A-01
Baseline Motor Power Draw at Different Operating Conditions	Stipulated based on a) spot or short-term wattage/rpm measurements (baseline is constant load) or b) short-term wattage/input measurements (baseline is variable load)	See VSD-A-01
Baseline Operating Hours*	Stipulated based on estimates or short-term pre-monitoring	a) Assumed equal to post-installation conditions which are monitored or b) if variable, then long-term pre-monitoring
Baseline Operating Conditions—Independent Variables that Impact Energy Use, Operating Hours**	Not used for method	Assumed equal to post-installation conditions which are monitored
Post-Installation* Motor Power Draw at Different Operating (Input) Conditions**	a) Stipulated based on manufacturer data, or b) spot or short-term wattage/rpm measurements	Continuous or regular interval wattage measurements
Post-Installation** Operating Conditions—Independent Variables that Impact Energy Use**	Not used for method	Long-term post-monitoring for input into post- and pre-installation model
ESCO Responsibility	None or short-term performance and operation	Performance and operation
Agency Responsibility	Performance and operation or long-term performance and operation only	None

*With some VSD projects, the replaced motors are always at constant load so that the baseline energy use is equal to the product of motor kW and motor operating hours.
**With some VSD projects, the replaced motors have variable loading depending on the independent factors such as weather, which impact valve or damper positions.
***Post-installation energy use can be directly measured.
****Post-installation energy use can be calculated based on measurement of independent variables such as weather once a correlation has been established between post-installation energy use and the independent variable.

Measure Category: Chiller Retrofits
Operating Factors: Operating hours, percent time at different loads
Performance Factors: kW/ton

Table 2.10: Chiller Retrofits—M&V Methods and Responsibilities

	Method			
	CH-A-01	**CH-A-02**	**CH-B-01**	**CH-B-02**
Option	**A**	**A**	**B**	**B**
Approach	No metering	Verification of chiller kW/ton ratings	Continuous metering of chiller (post-installation)	Continuous metering of chiller and cooling load (post-installation)
Inventory of Chillers and Auxiliary Equipment	Survey which is checked to defined accuracy	See CH-A-01	See CH-A-01	See CH-A-01
Verification of System Operation	Function verification of chiller system operation	See CH-A-01	See CH-A-01	See CH-A-01
Baseline Chiller and Auxiliary Equipment Power Draw (at different cooling loads)	Stipulated based on manufacturer data and/or other sources	a) Stipulated, or b) spot or short-term kW/ cooling load measurements to determine performance curve or kW vs. cooling load	See CH-A-02	See CH-A-02
Baseline Cooling Load (stated in average ton hours per year or percent time at different cooling loads)	Stipulated based on estimates (e.g., computer model simulation)	See CH-A-01	a) Stipulated, or b) assumed equal to post-installation cooling load which is etermined from measurement of new chiller kW and use of new chiller performance curve	Assumed equal to post-installation load which is continuously measured

	Method			
	CH-A-01	**CH-A-02**	**CH-B-01**	**CH-B-02**
Post-Installation Chiller and Auxiliary power Draw (at different cooling loads)	Stipulated based on anufacturer data and/or other sources	a) Stipulated, or b) spot or short-term kW/ cooling load measurements to determine performance curve kW vs. cooling load	Continuous or regular interval metering of chiller kW to determine post-installation energy use	See CH-B-01
Post-Installation Cooling Load (stated in average ton hours per year or percent time at different cooling loads)	Stipulated based on estimates	See CH-A-01	Not required for this method	Post-installation cooling load is determined from measurement of water or air flows and temperatures
ESCO Responsibility	None	None or performance	Performance and operation	Performance and operation
Agency Responsibility	Performance and operation	Performance and operation or operation only	None	None